

## Progress Report on GEANT Study of Containerized Detectors

### What's New Since Last Time?

- More detailed container description in GEANT
  - Slightly less steel in new container
  - Slightly larger gaps
- RPC efficiency of 95% implemented
- Cross-talk implemented
- Plywood absorber rather than plastic + air
- Generating large samples of events on the Farm
- Generated beam  $\nu_e$  samples
- New event number normalizations (used LOI numbers last time)

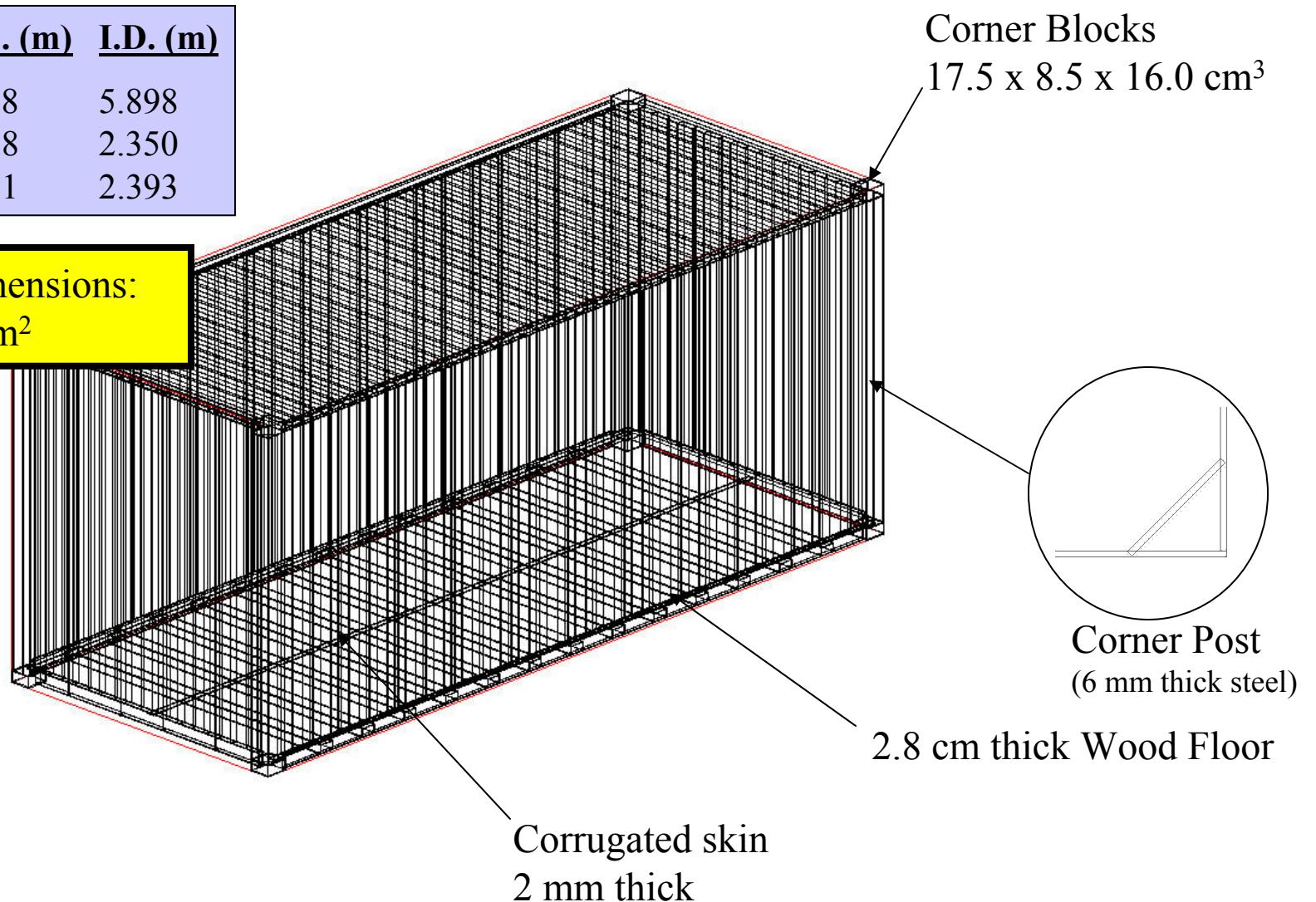
## General Strategy

- Implement containerized detectors in GEANT.
- Use MINOS event generator with a flat energy distribution
- Weight interaction vertex in GEANT by number of target nucleons in various materials
- Parabolic fit to multiple tracks in an event. Assume longest track is electron.
- Weight final distributions by evolved energy distribution of the beam
- Generate event samples with:
  - Interaction vertex in transverse center of a container
  - Interaction vertex uniformly distributed
  - All steel structures replaced with air

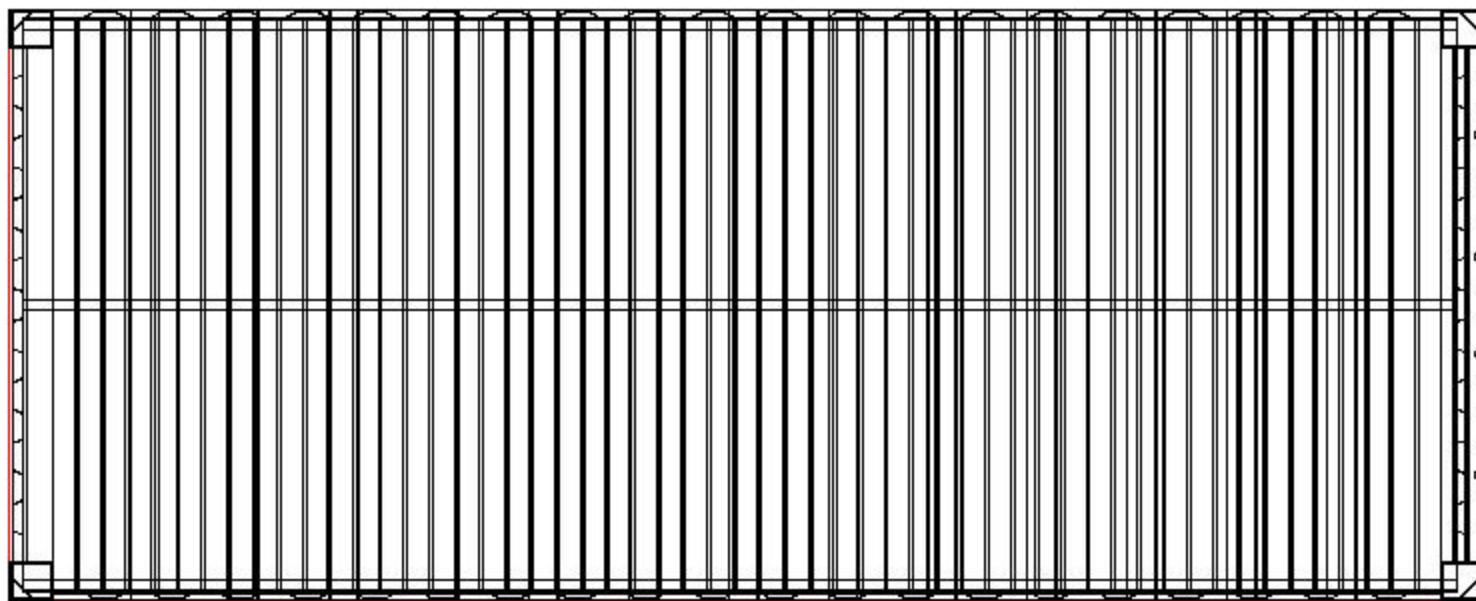
# GEANT Implementation

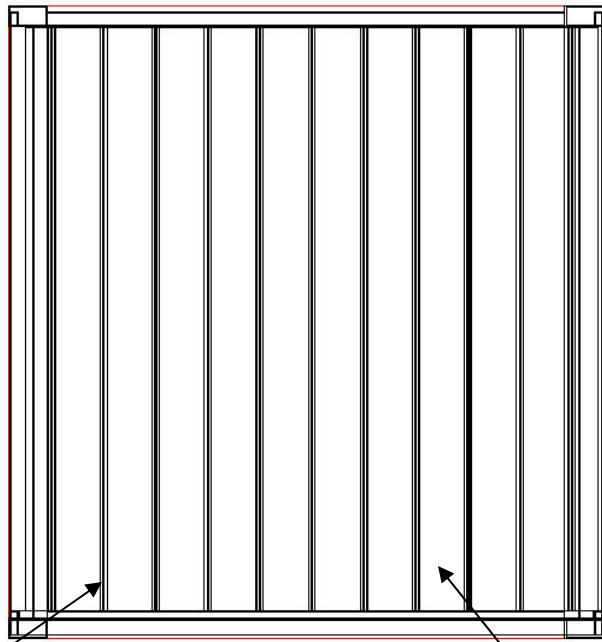
	<u>O.D. (m)</u>	<u>I.D. (m)</u>
Length	6.058	5.898
Width	2.438	2.350
Height	2.591	2.393

Detector dimensions:  
 $5.89 \times 2.39 \text{ m}^2$



Top View





RPC

11 planes per container

x, y readout at each station

3 cm cells

Plywood Absorber

10 full layers + 2 half layers

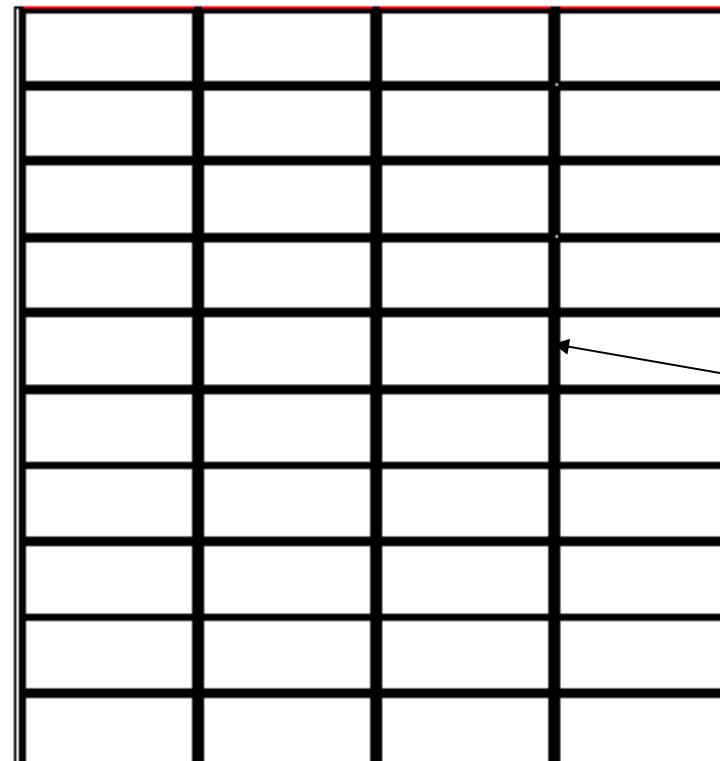
Full layers 18.3 cm thick,  $1/3 X_0$

## 50 kton Detector 4 x 10 x 50 Stack of Containers

20.1 cm horizontal and  
19.8 cm vertical gaps  
between detectors in  
adjacent containers.

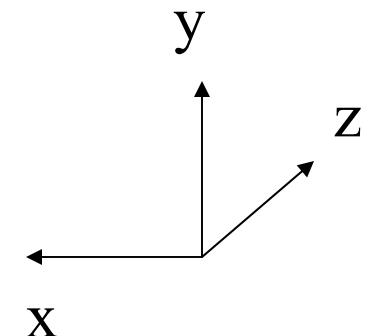
Vertical gap determined  
by difference between  
inside and outside dim.  
of container.

Horizontal gap  
determined by container  
dimensions and cell  
guide spacing



50 kt of absorber  
2.1 kt of steel  
0.7 kt of wood  
0.14 kt of Al.

Cell Guides



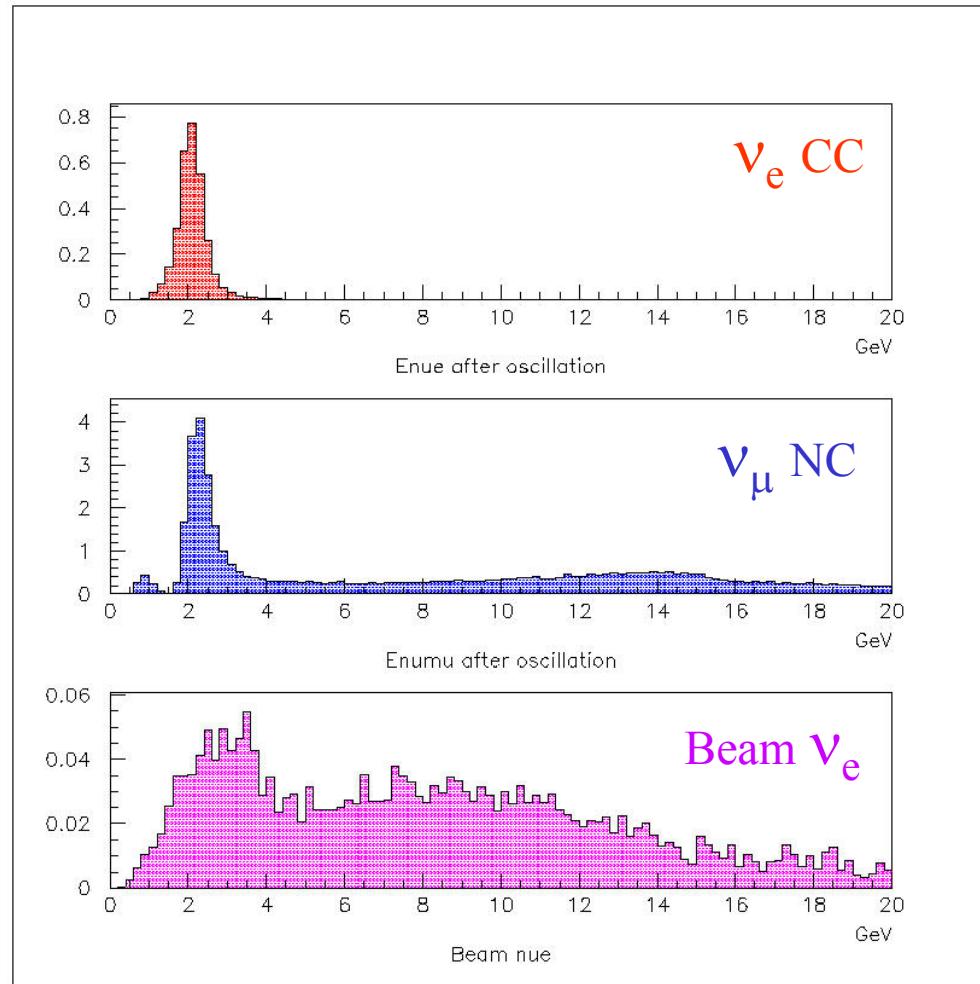
## Neutrino Energy Spectra

Flat neutrino spectrum generated between 0.5 - 3.5 GeV for  $\nu_e$  and 0.5 - 20 GeV for  $\nu_\mu$  and Beam  $\nu_e$ .

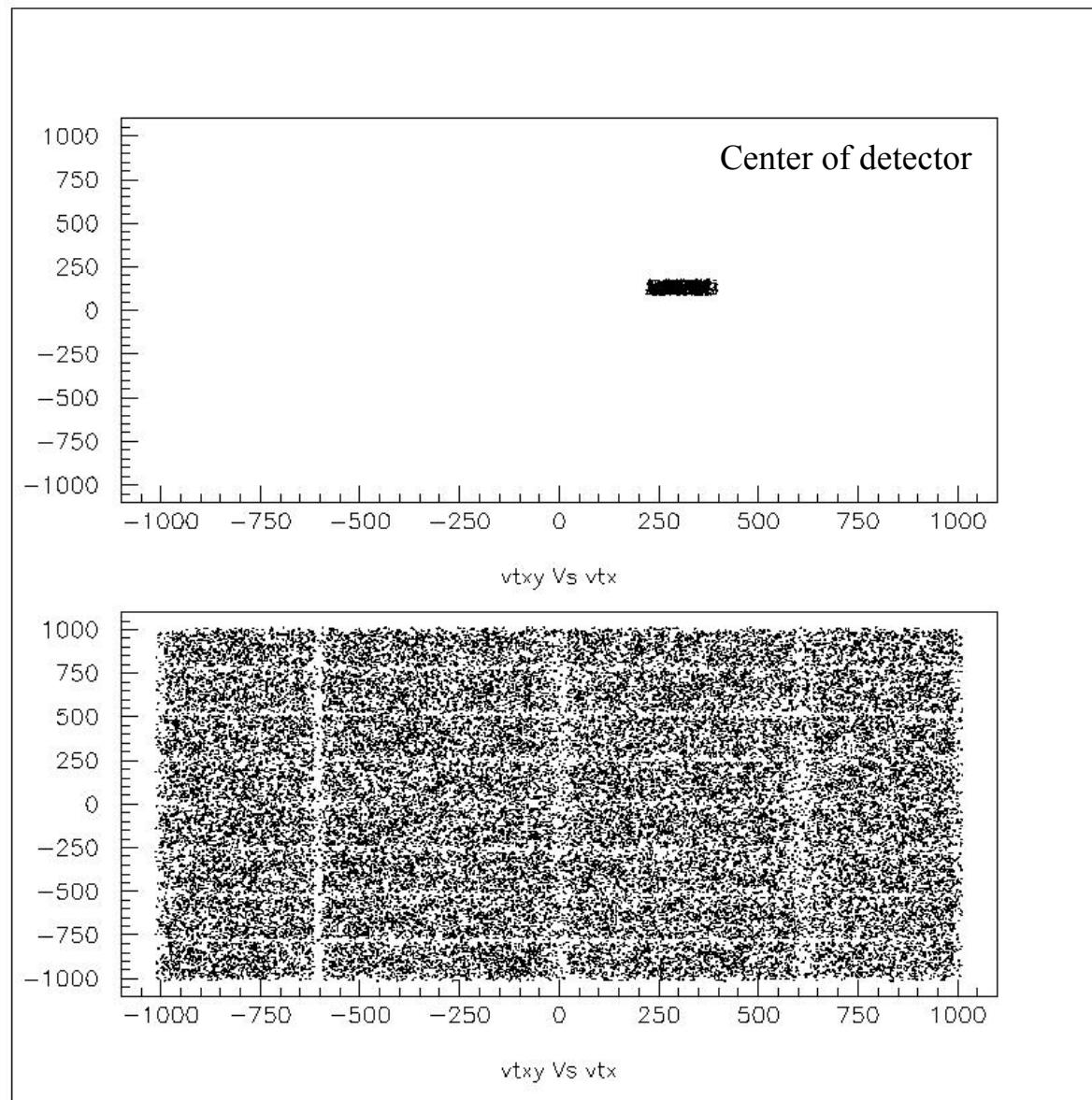
Weight applied at ntuple level.

Expected Number of events after oscillation for 50 Kt detector, 5 yr run, 85% fiducial, before cuts:

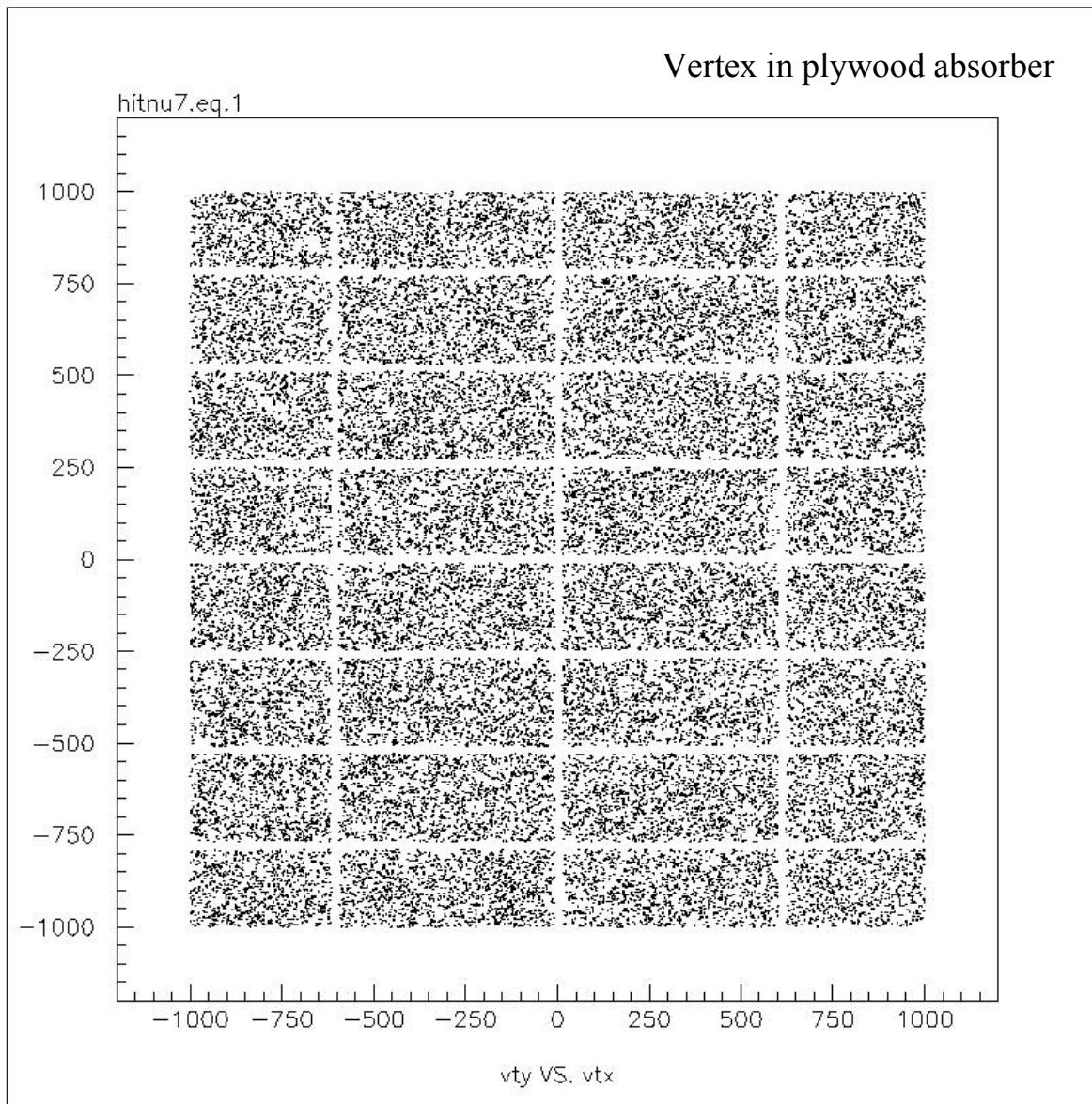
$\nu_e$ CC	669
$\nu_\mu$ NC	6878
Beam $\nu_e$	463



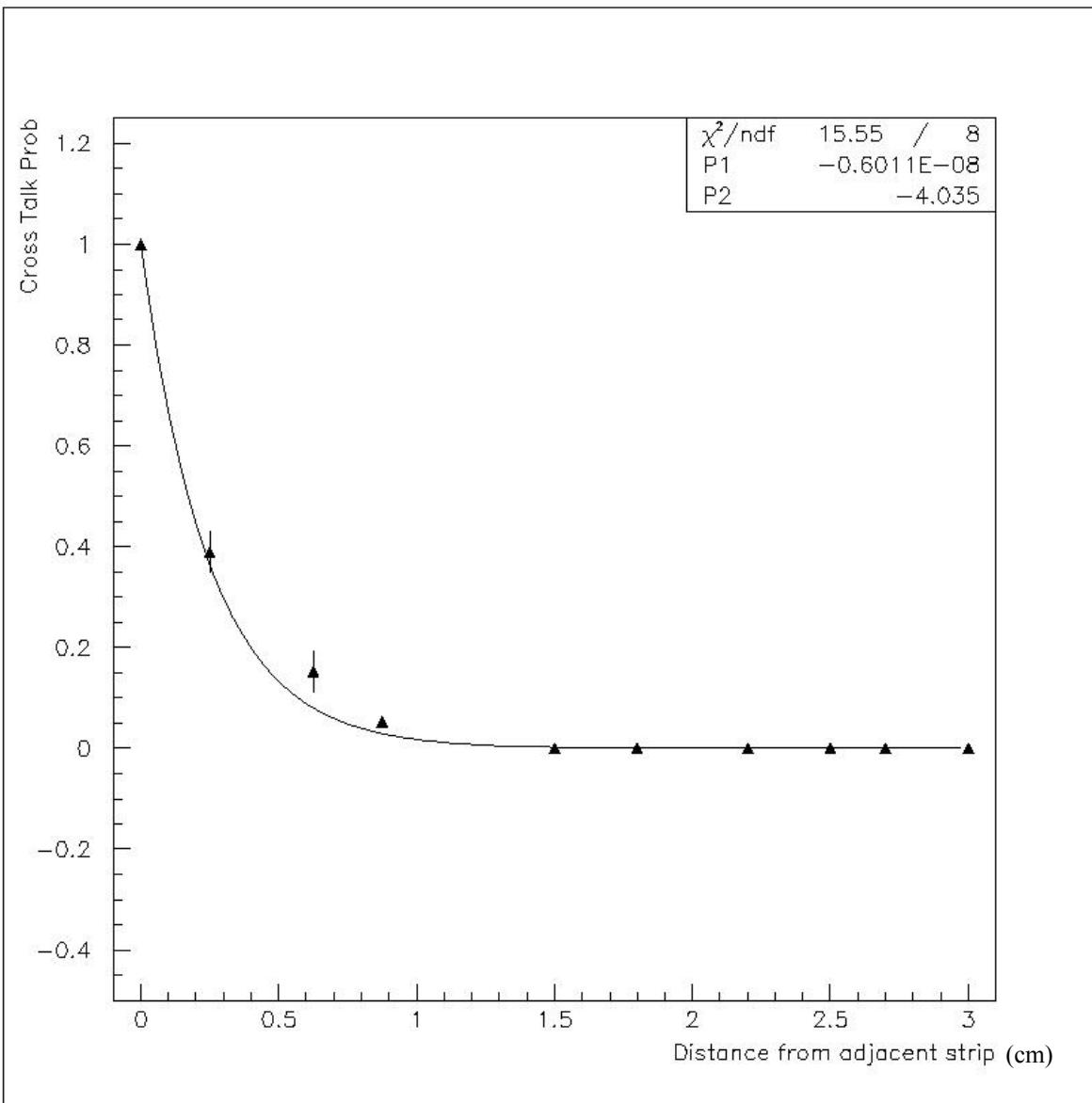
## Vertex Distributions



## Vertex Distribution



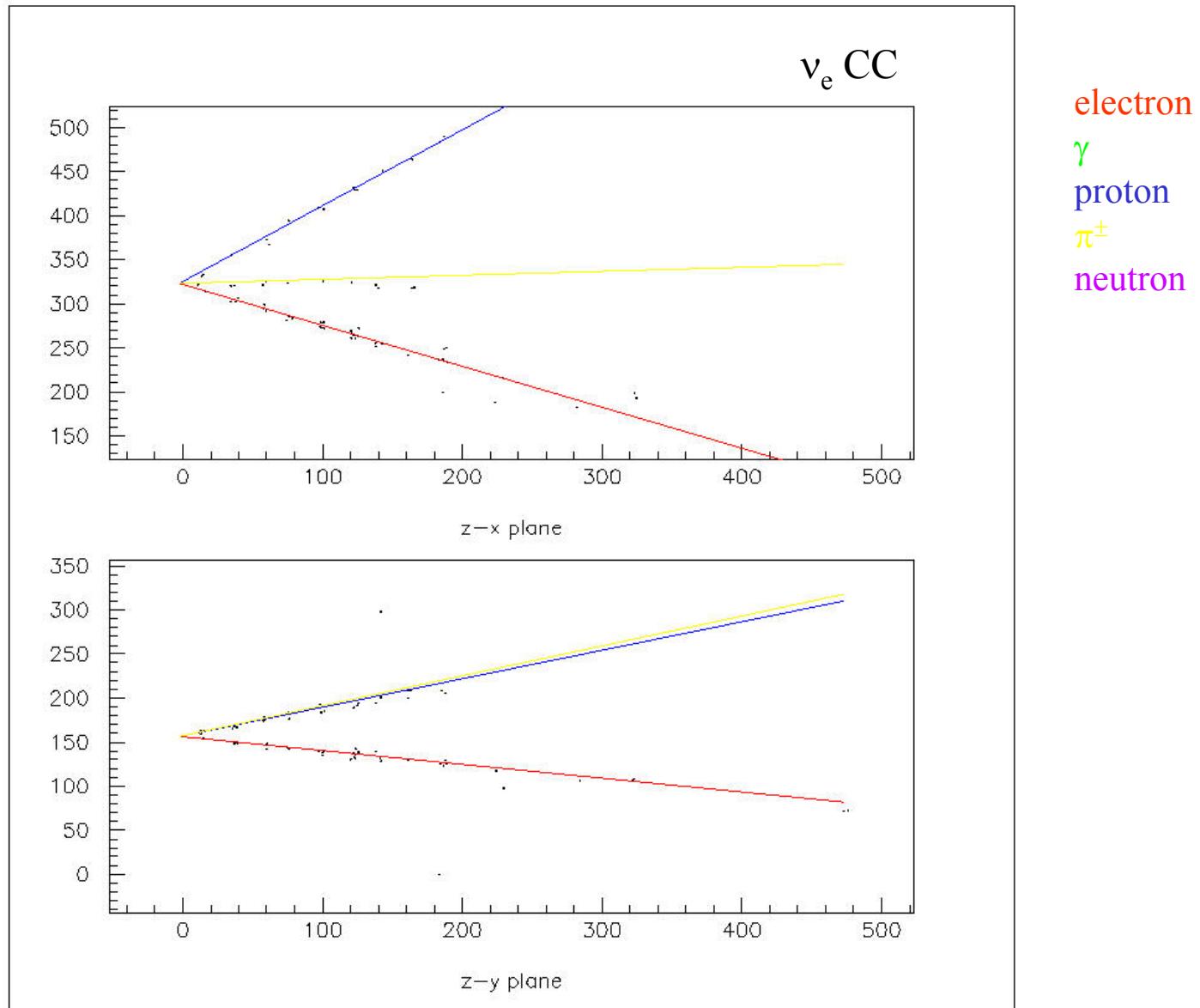
## Cross Talk Implemented in GEANT



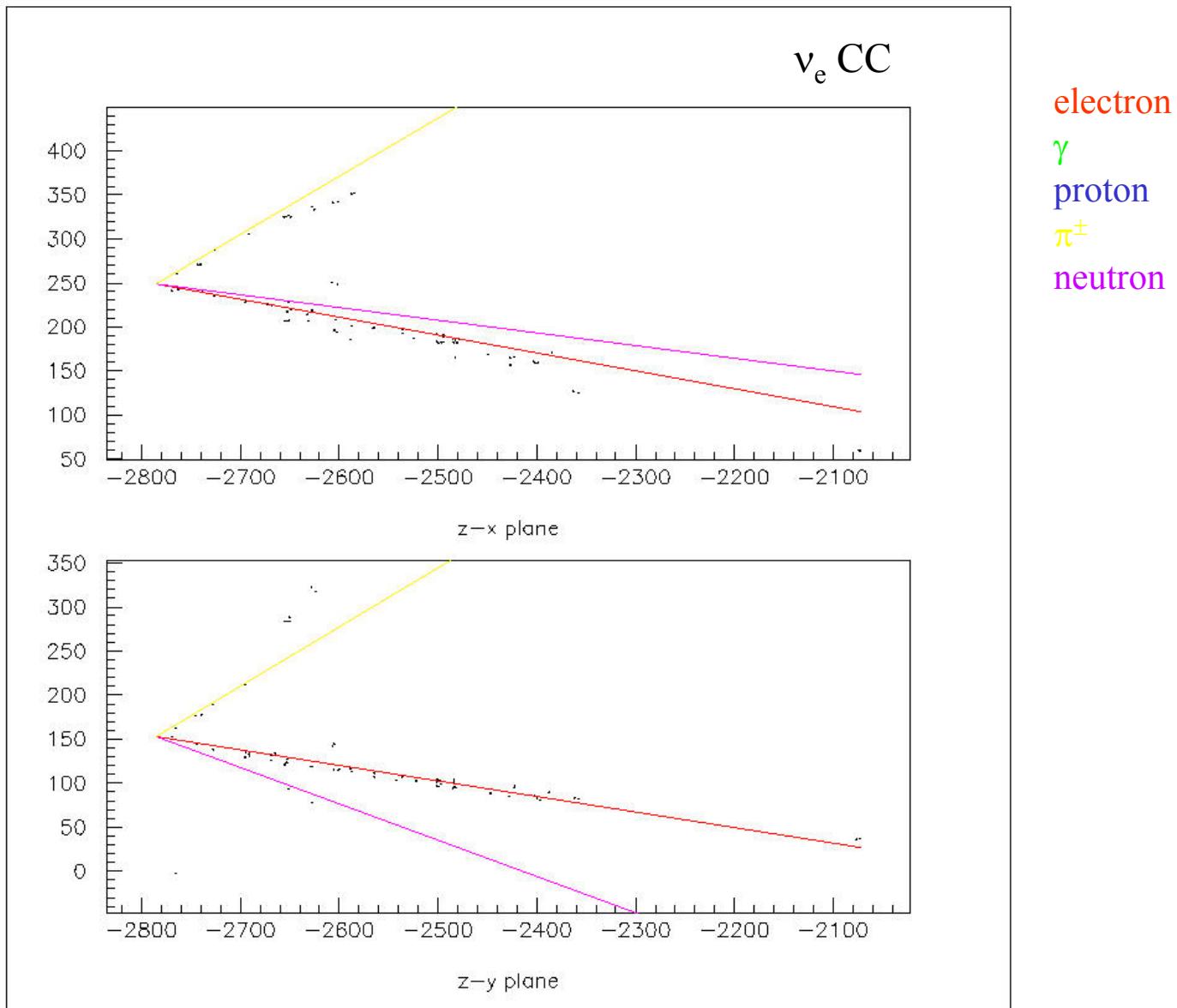
Data provided  
by Valeri.

New measurements  
are 4X better.

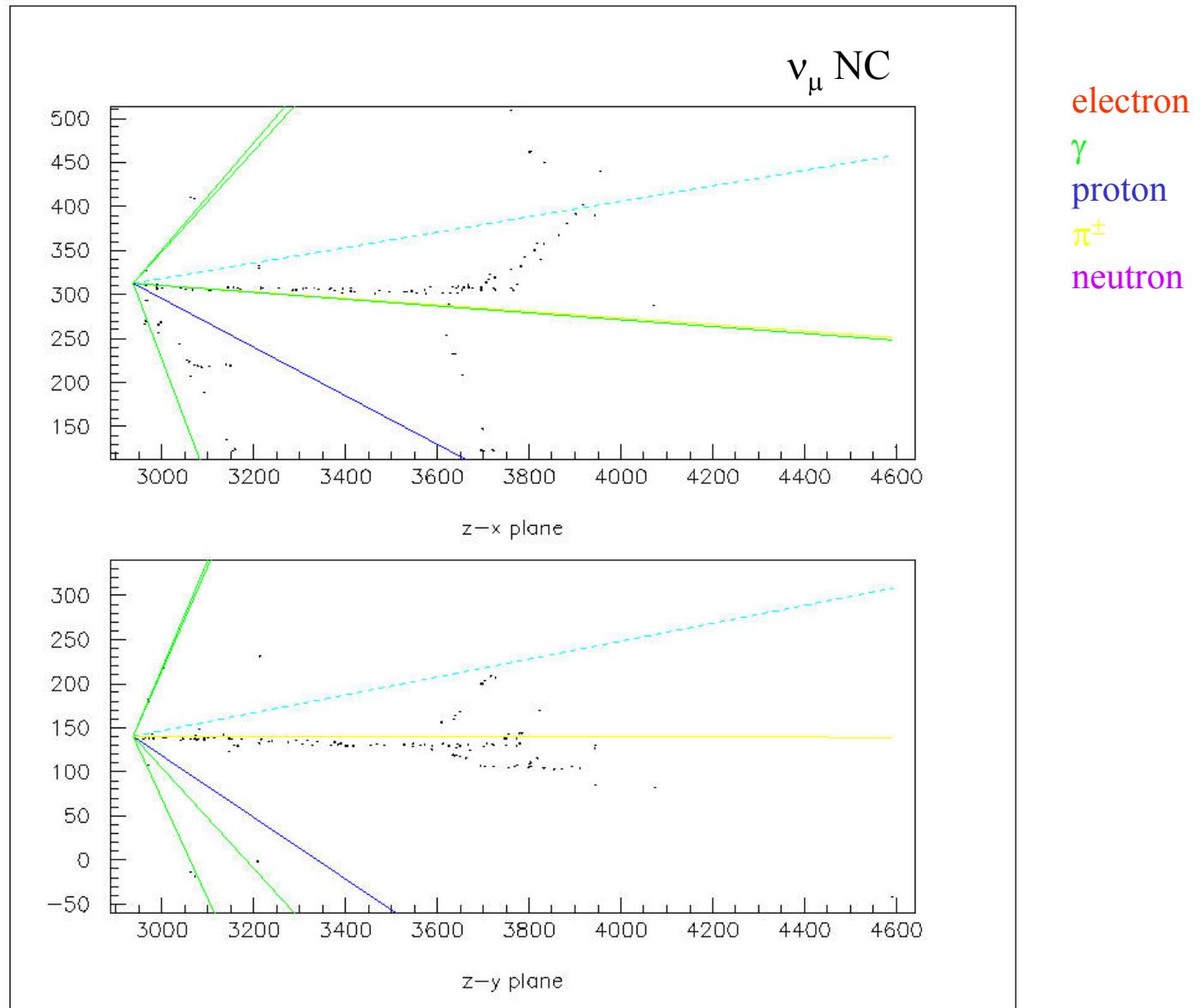
## Event Display Using NUGEN Input



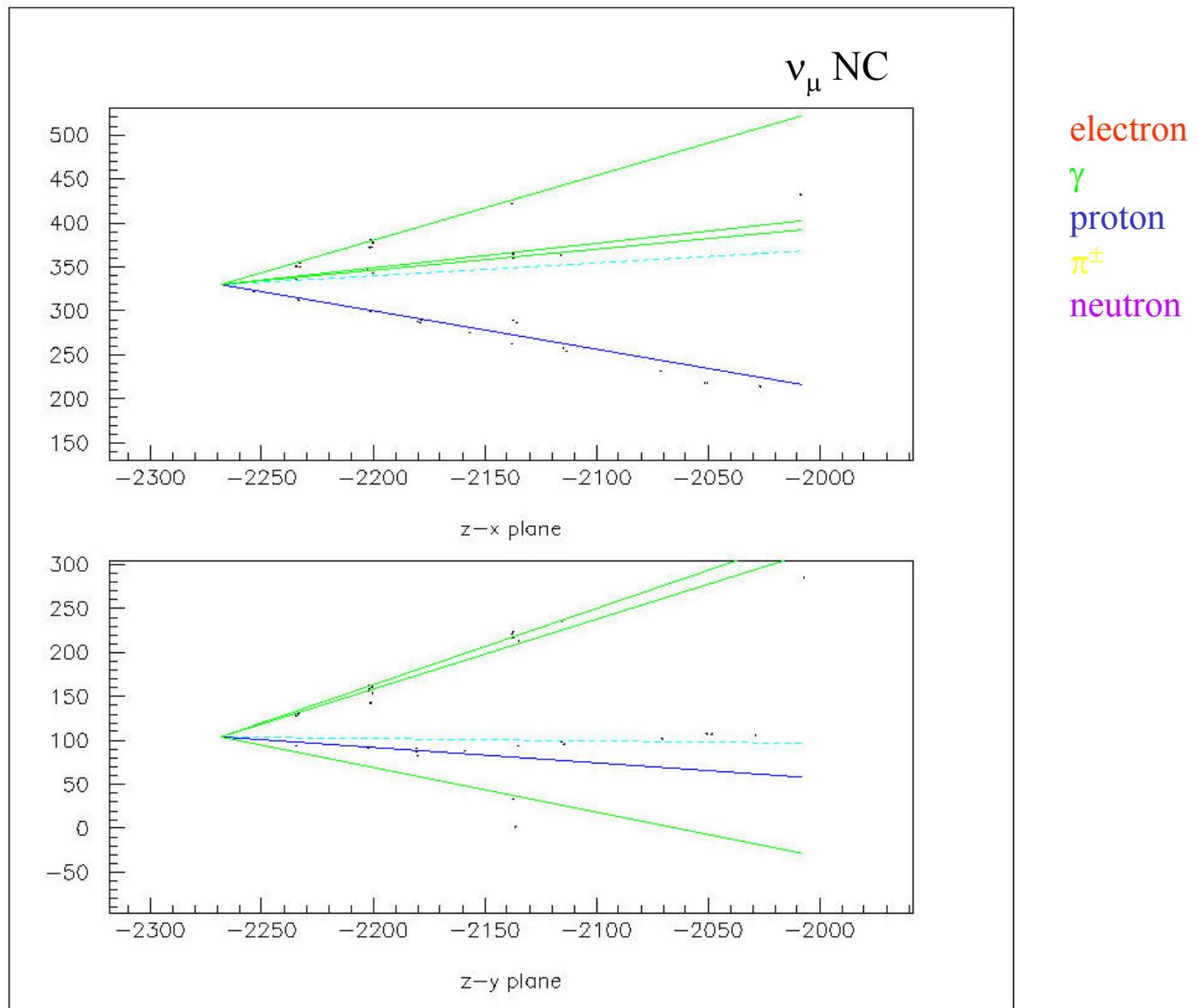
# Event Display Using NUGEN Input



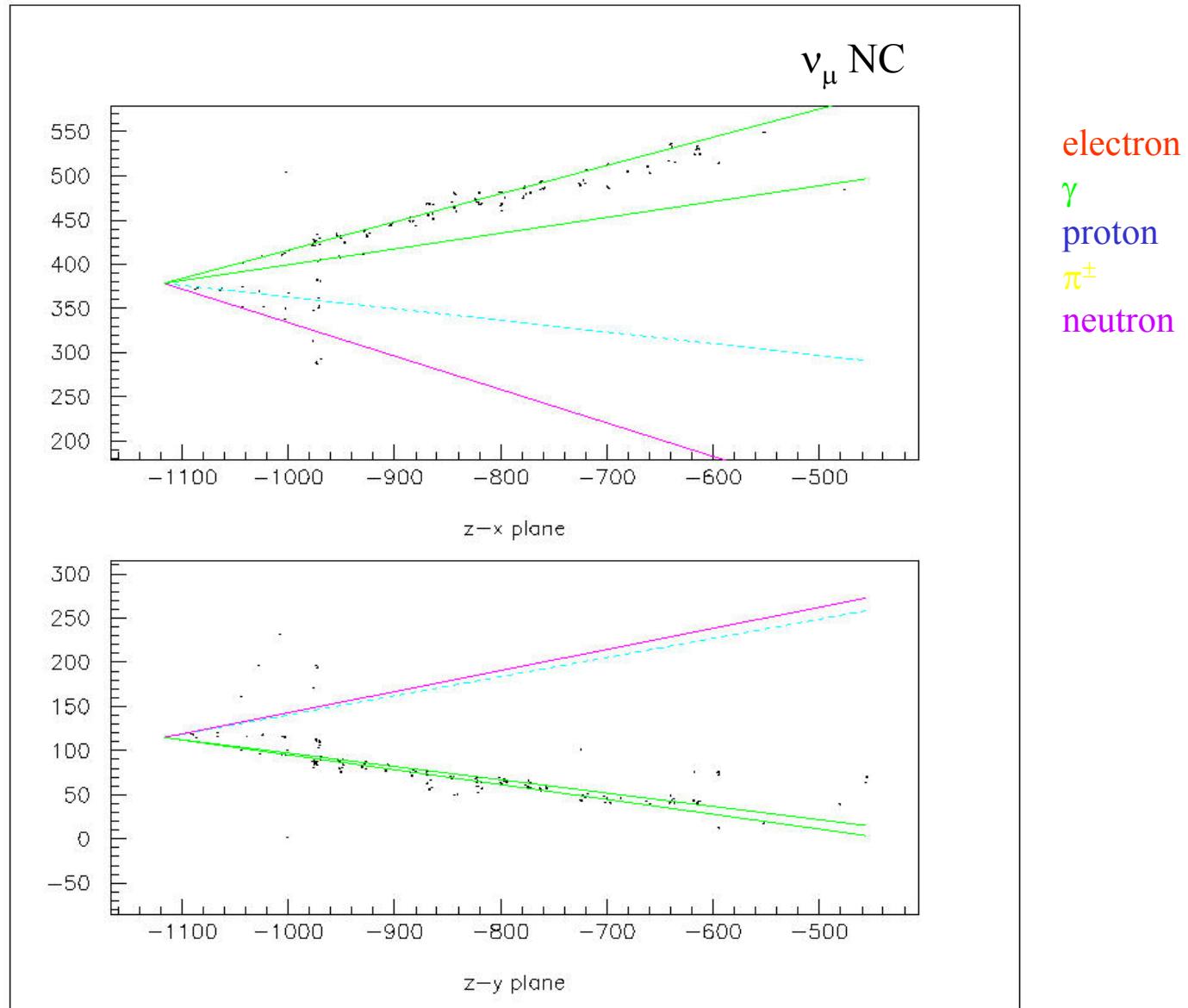
## Event Display Using NUGEN Input



## Event Display Using NUGEN Input



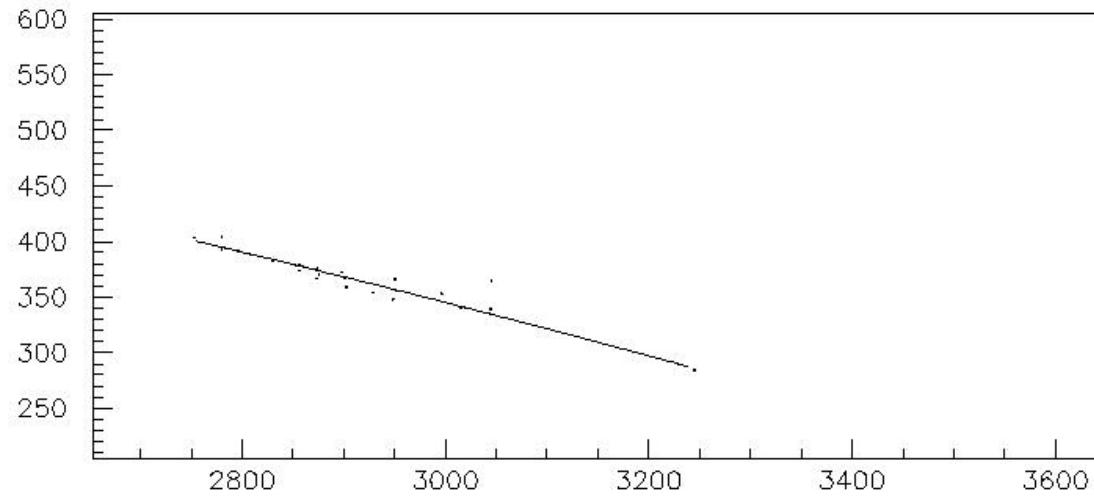
## Event Display Using NUGEN Input



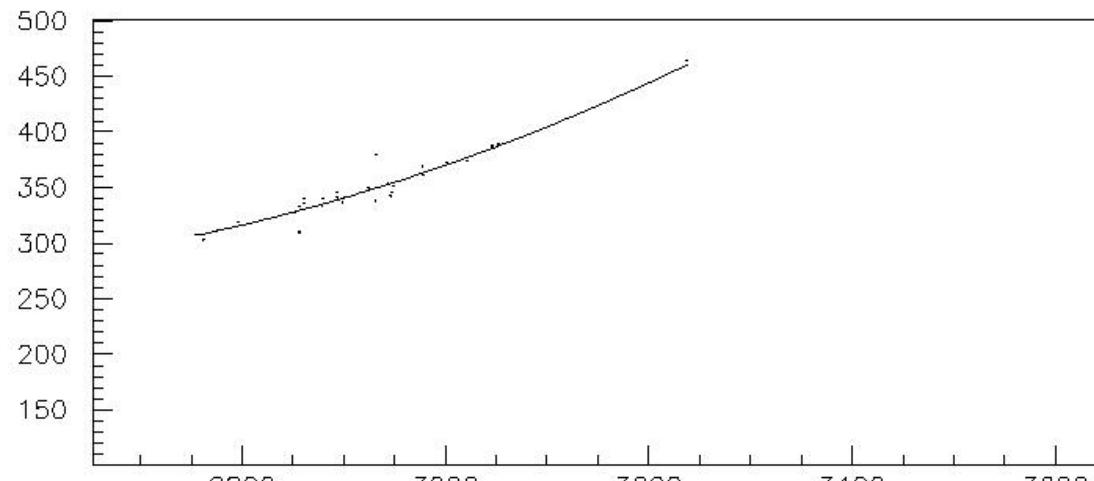
## Event Reconstruction

- Hough Transform - step through slope and intercept space
- Find best straight line fit. Iterate.
- Assign hits within  $\pm 15$  cm of fit to track.
- Final parabolic fit to track.
- Eliminate all but the first few hits on track from further consideration
- Repeat to look for additional tracks.

## $v_e$ charged current

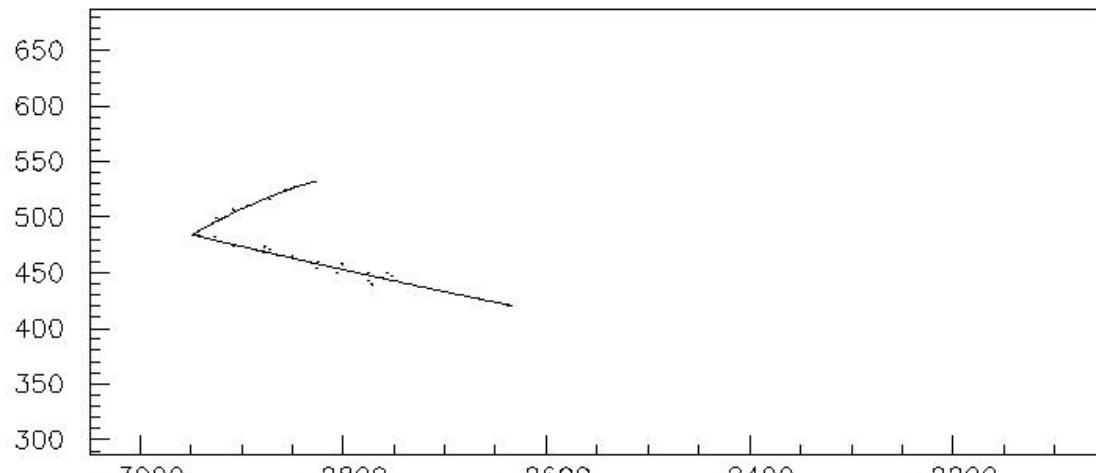


$z-x$  plane

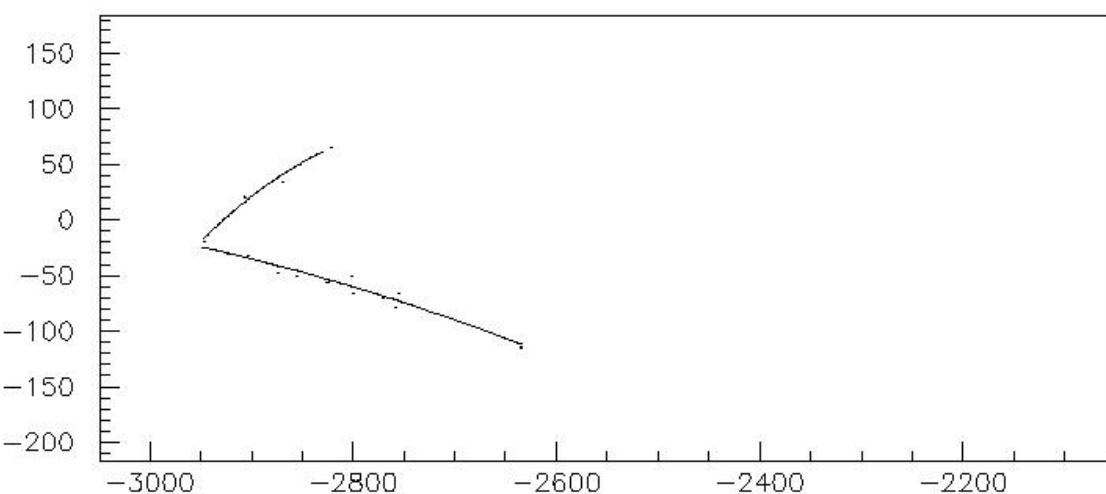


$z-y$  plane

## $\nu_e$ charged current

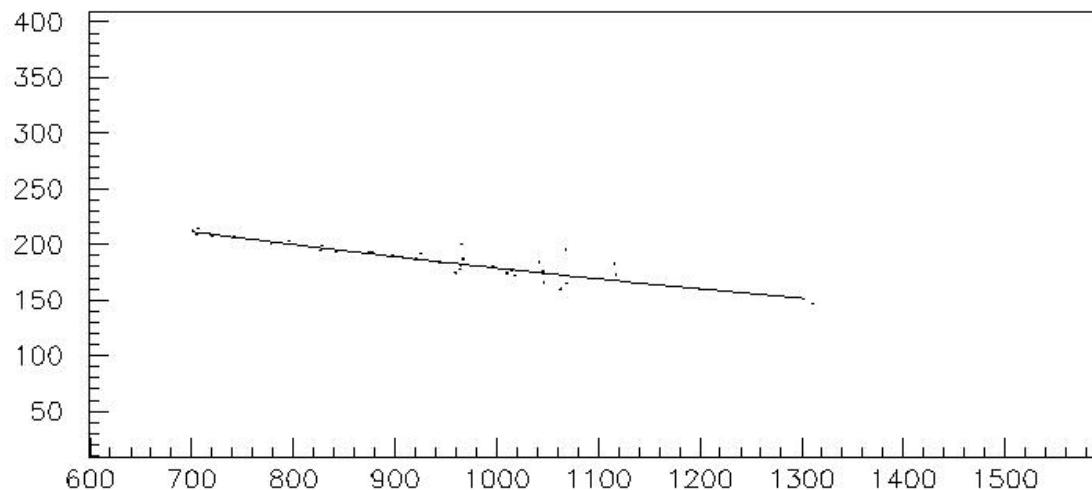


$z$ - $x$  plane

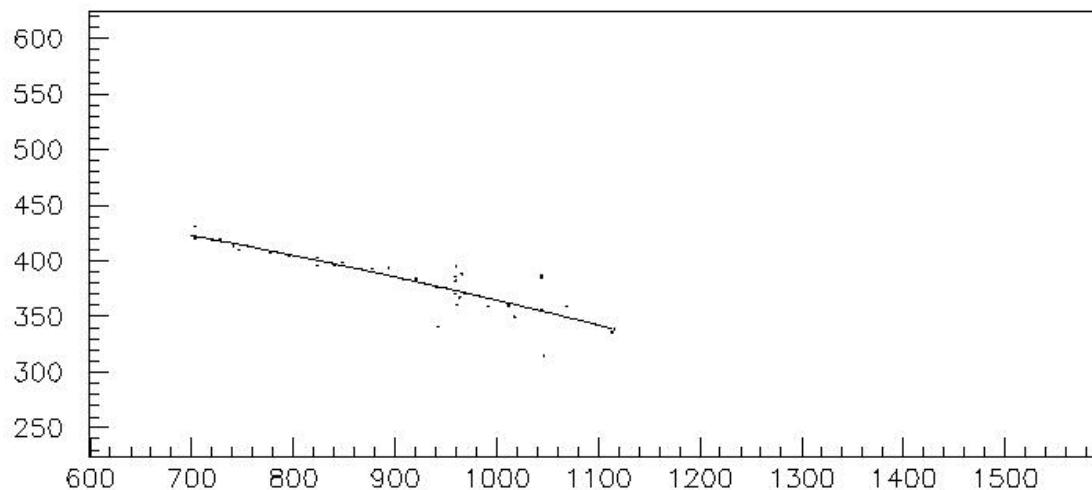


$z$ - $y$  plane

## $v_e$ charged current

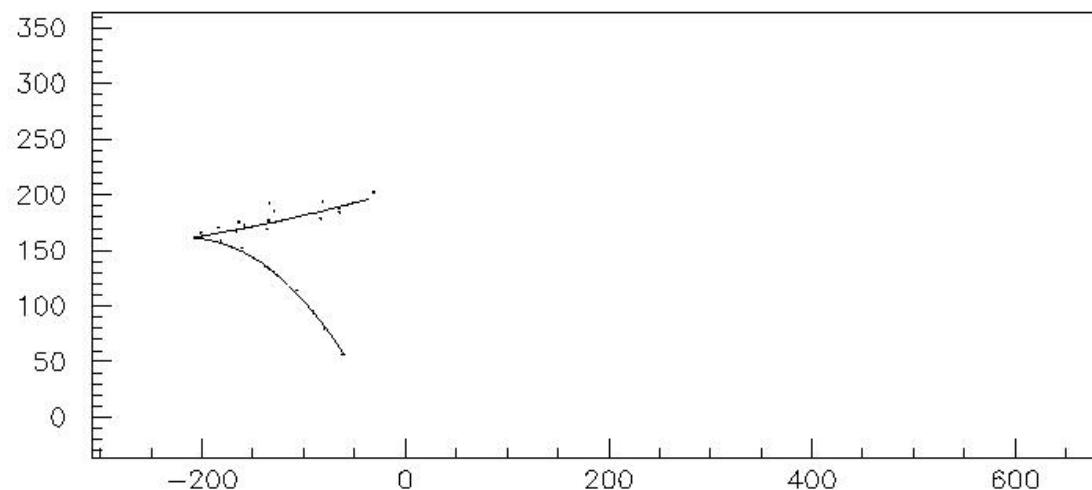


$z-x$  plane

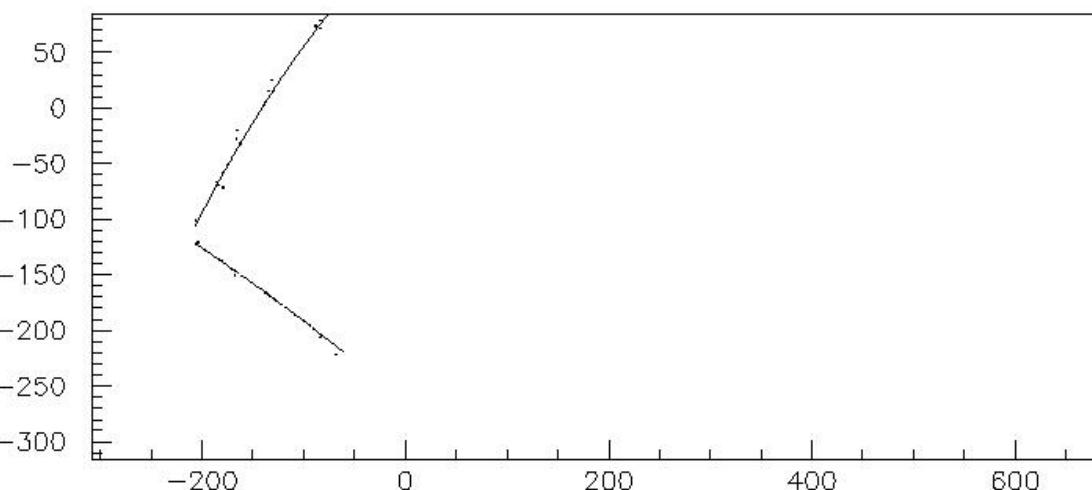


$z-y$  plane

## $v_e$ charged current

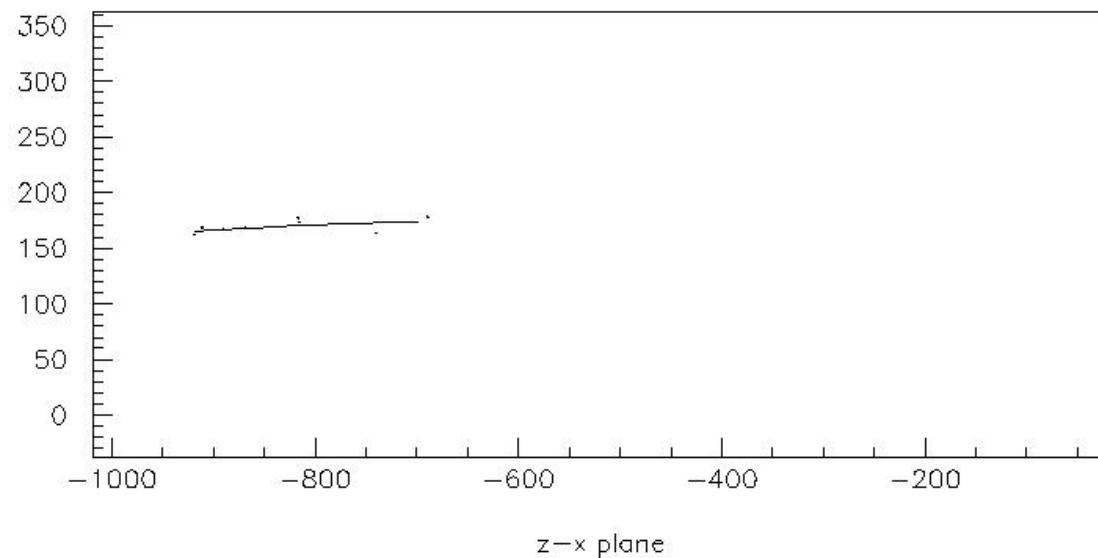


$z$ - $x$  plane

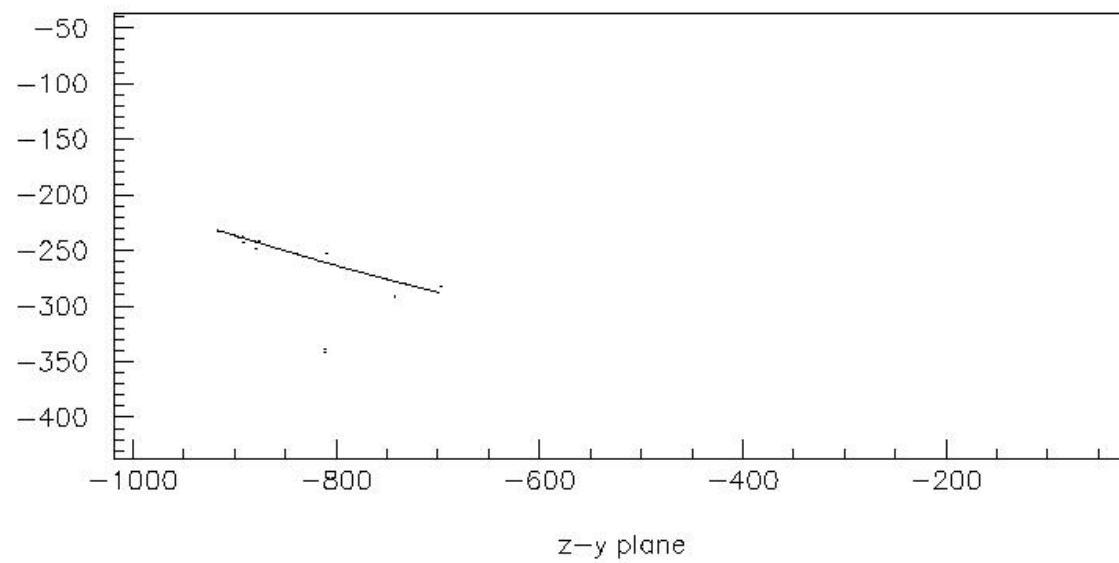


$z$ - $y$  plane

# $\nu_\mu$ Neutral Current

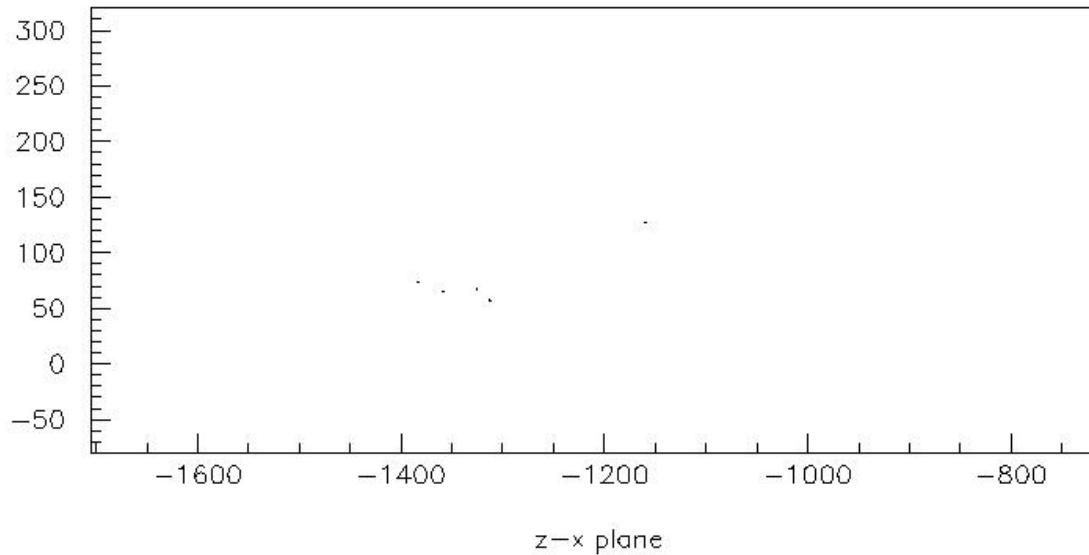


$z$ - $x$  plane

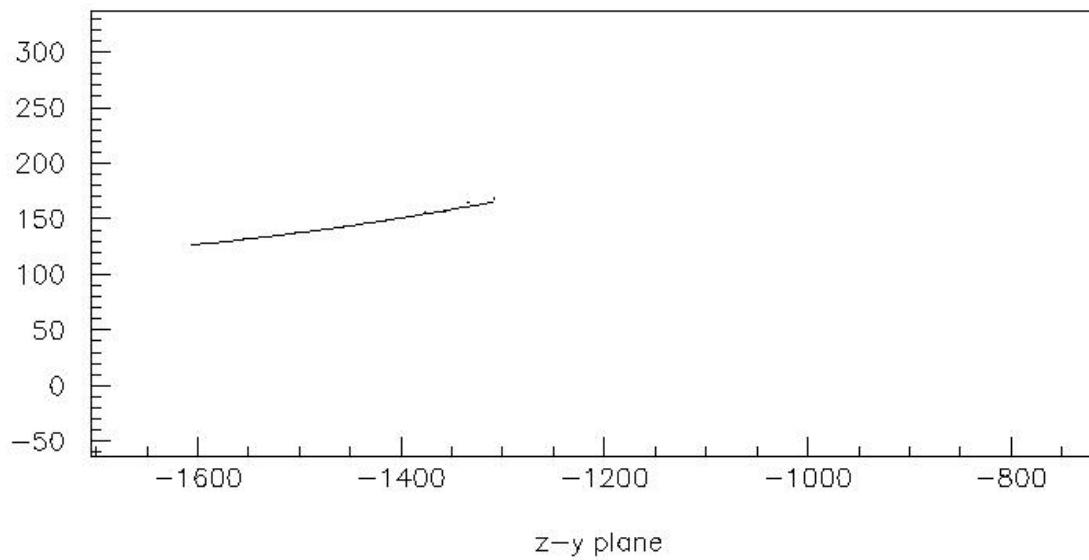


$z$ - $y$  plane

# $\nu_\mu$ Neutral Current

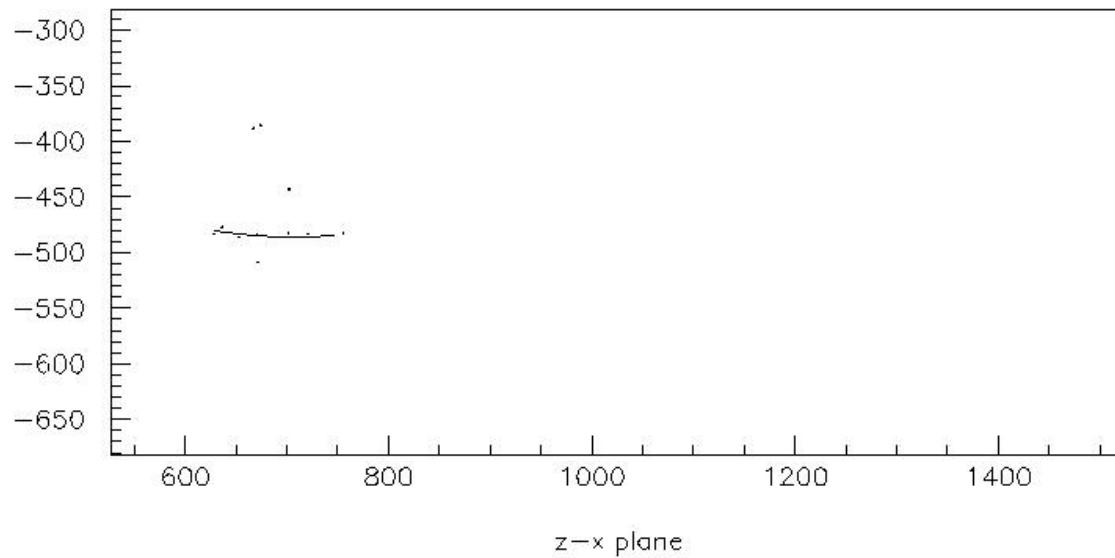


$z-x$  plane

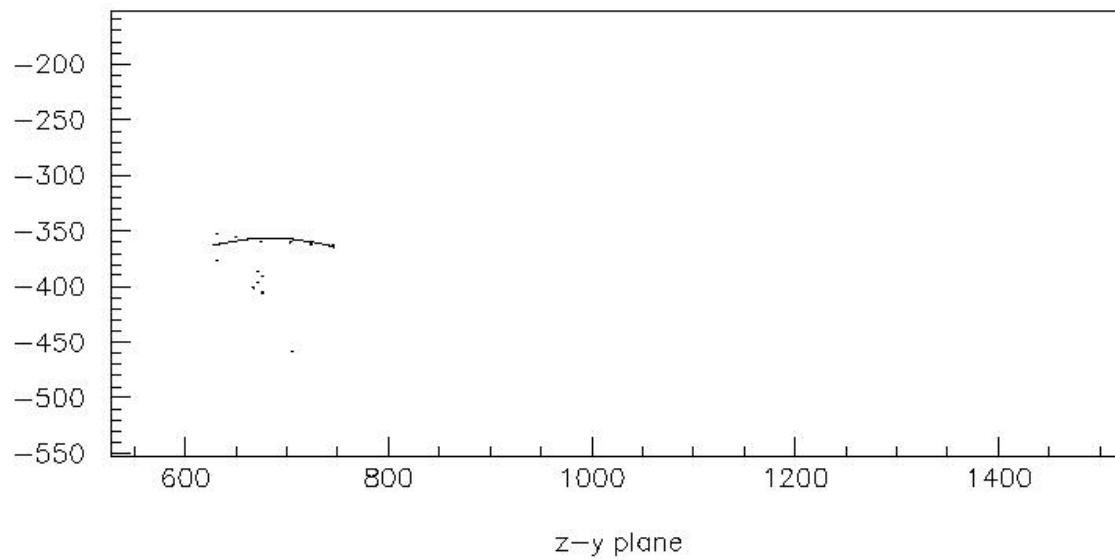


$z-y$  plane

## $\nu_\mu$ Neutral Current

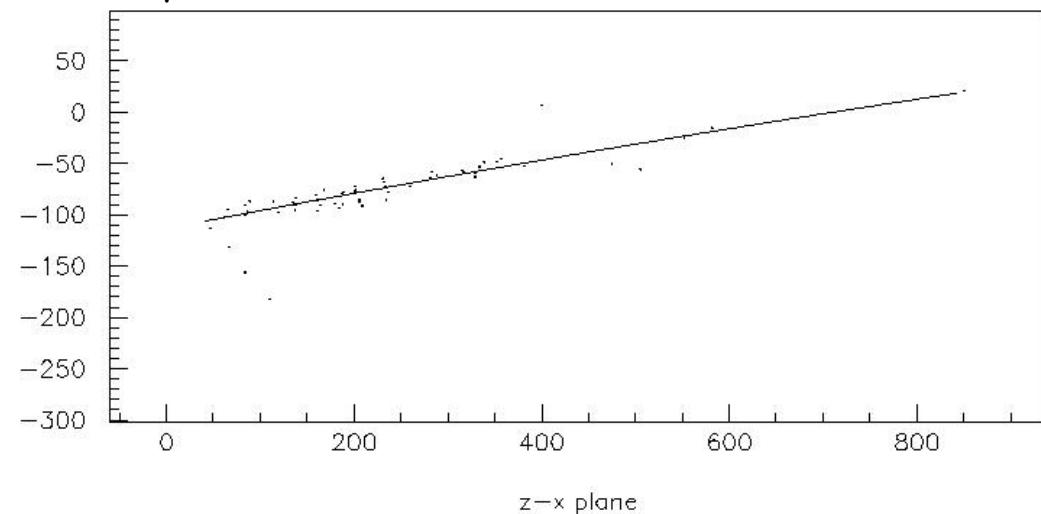


$z-x$  plane

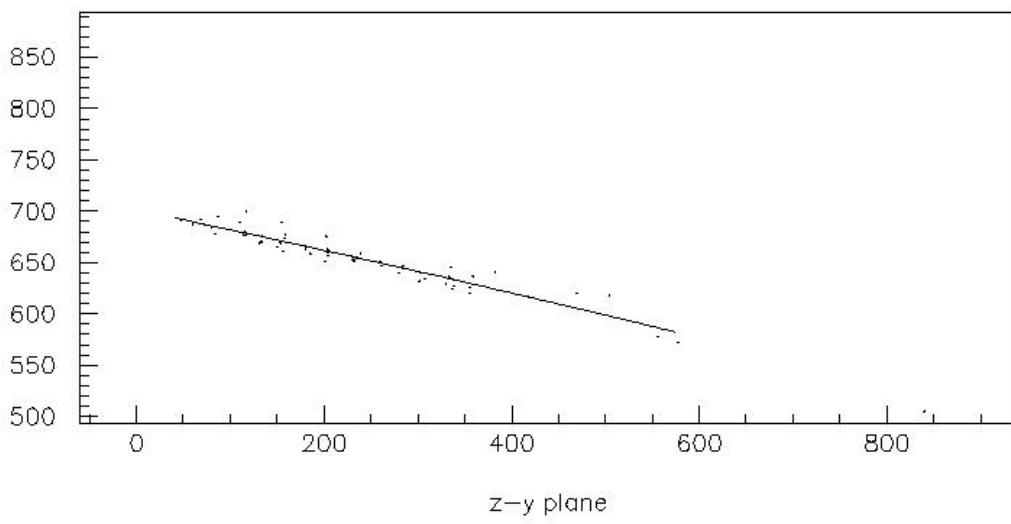


$z-y$  plane

## $\nu_\mu$ Neutral Current that Passes Cuts



z-x plane



z-y plane

## CUTS

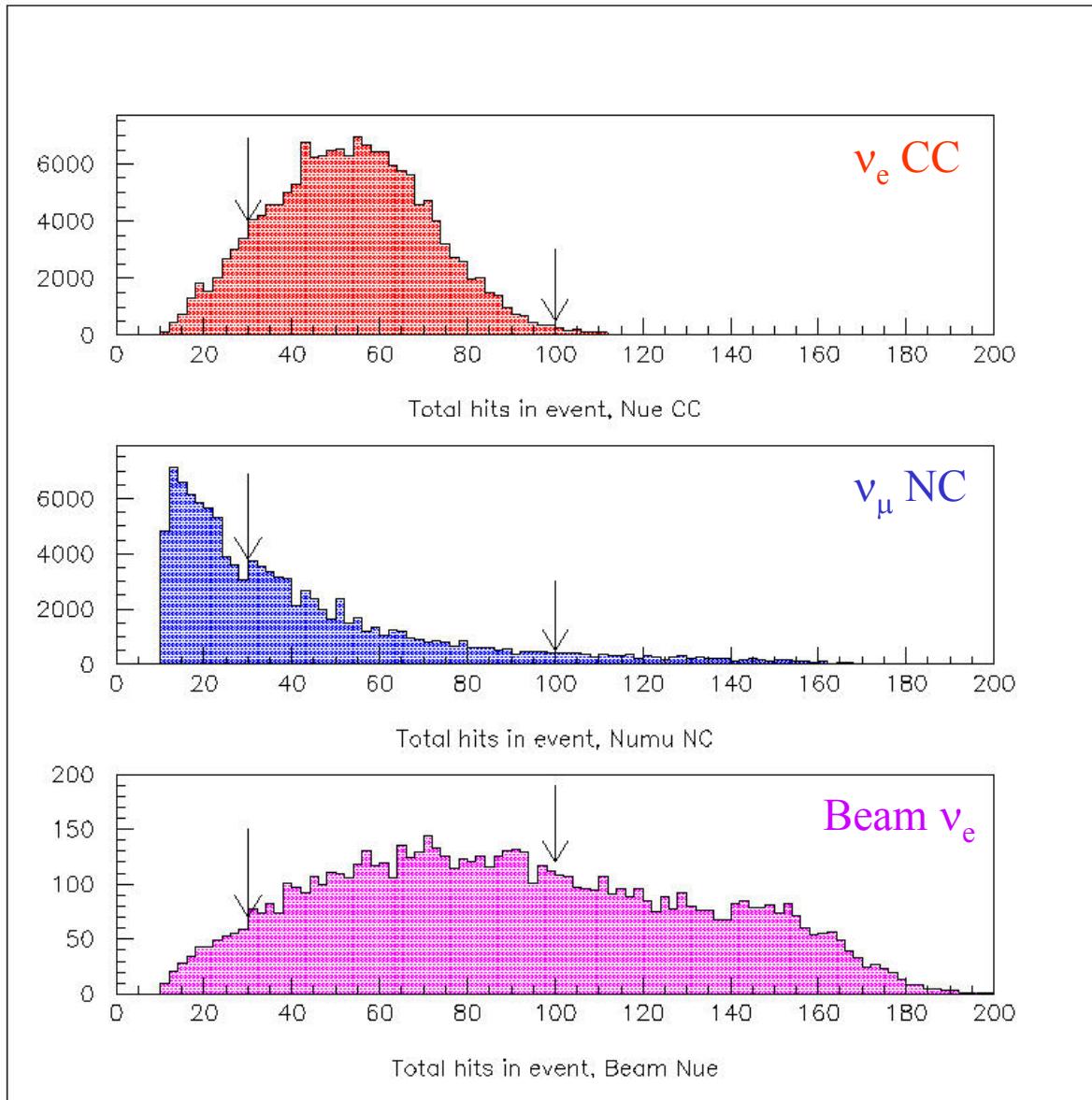
### Basic Reconstruction cuts to reduce ntuple size:

- $\geq 1$  reconstructed track in each view
- $\chi^2$  of longest track in each view  $< 100$
- Total number of hits  $< 150$

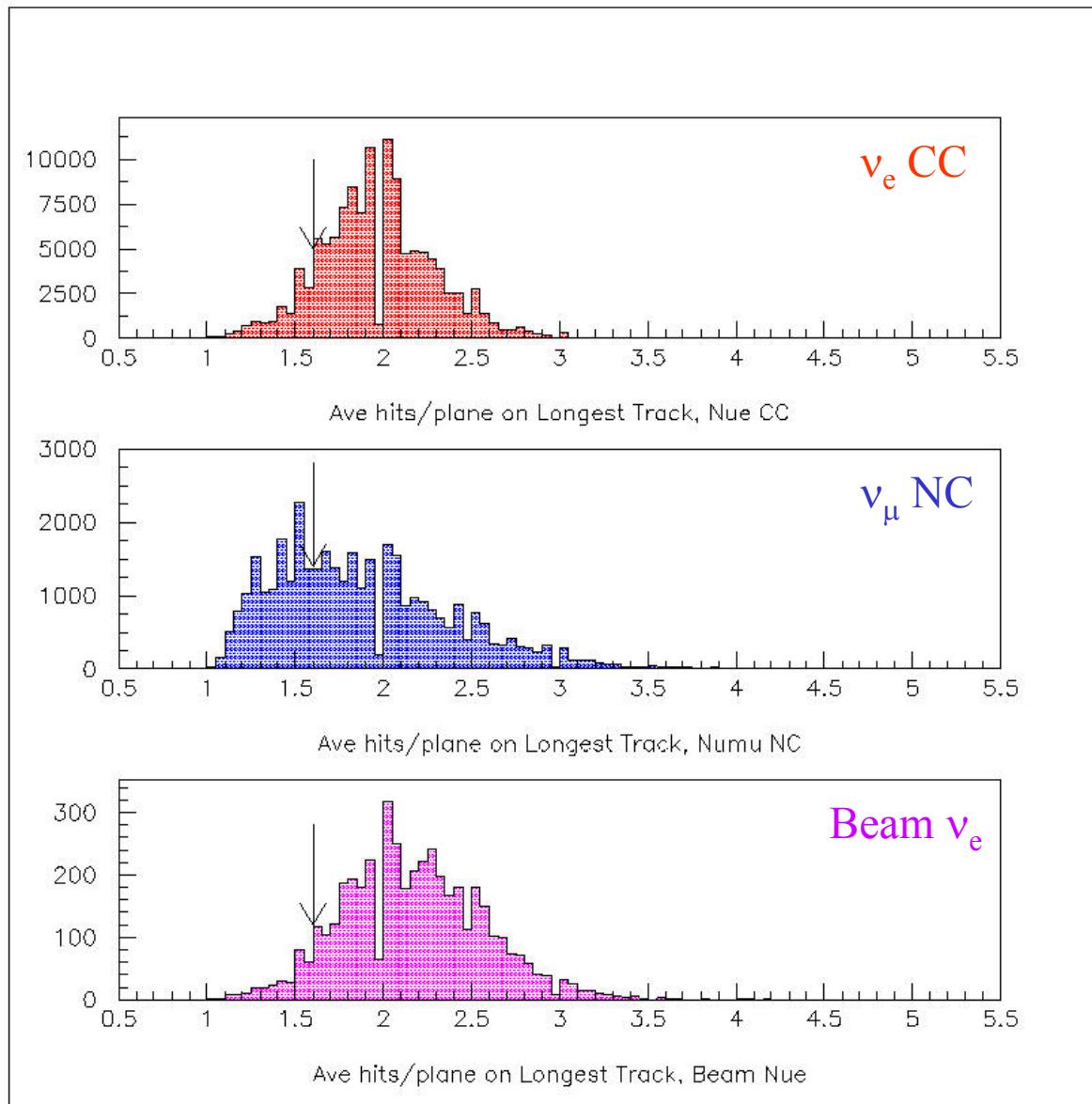
### Analysis cuts at ntuple level

- $30 < \text{Total Hits} < 100$
- $> 1.6$  hits/plane ave for longest track in each view
- Width of longest track (RMS) in each view  $< 8.5 \text{ cm}^2$
- Fraction of hits on longest track/total hits  $> 0.575$ , in each view
- $12 < \text{number of hit planes} < 25$  in each view
- $20 - 50$  hits on longest track in each view

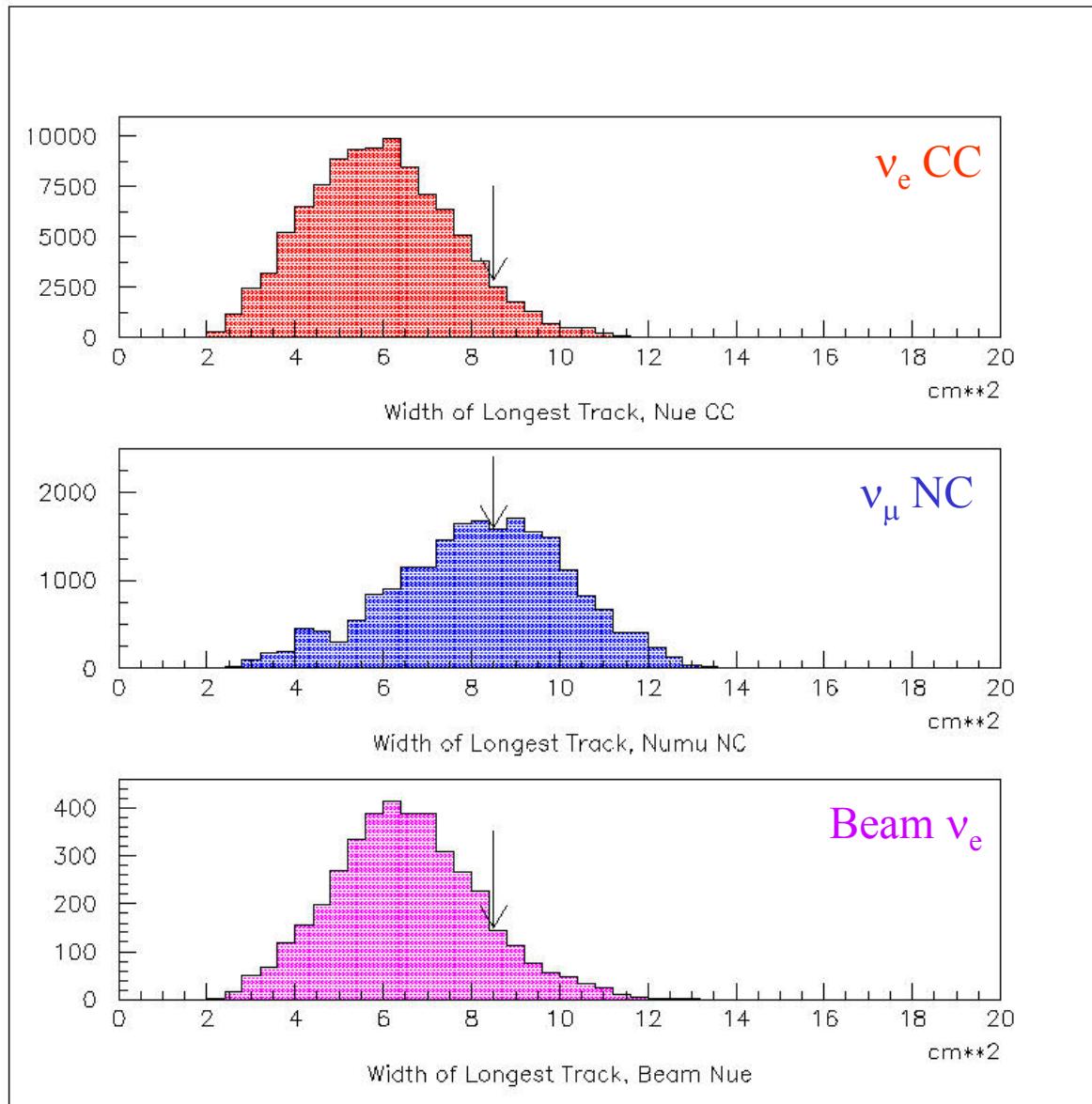
Calculate Figure of Merit = signal events/sqrt( $\nu_e$  beam +  $\nu_\mu$  NC)  
Number of events normalized to flux for 50 kton detector x  
5 years of data x 85% fiducial volume.



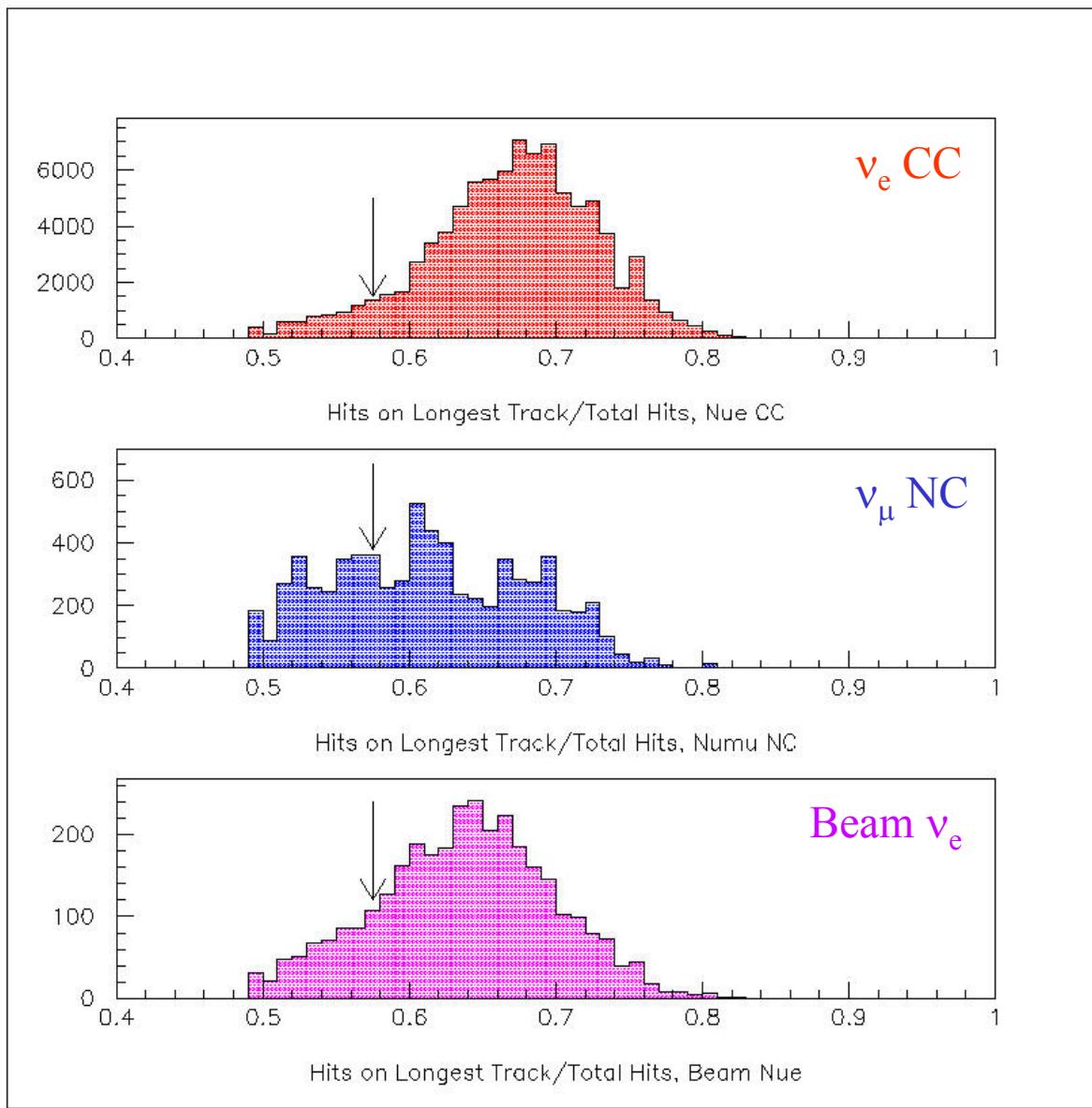
Distributions  
are weighted,  
successive



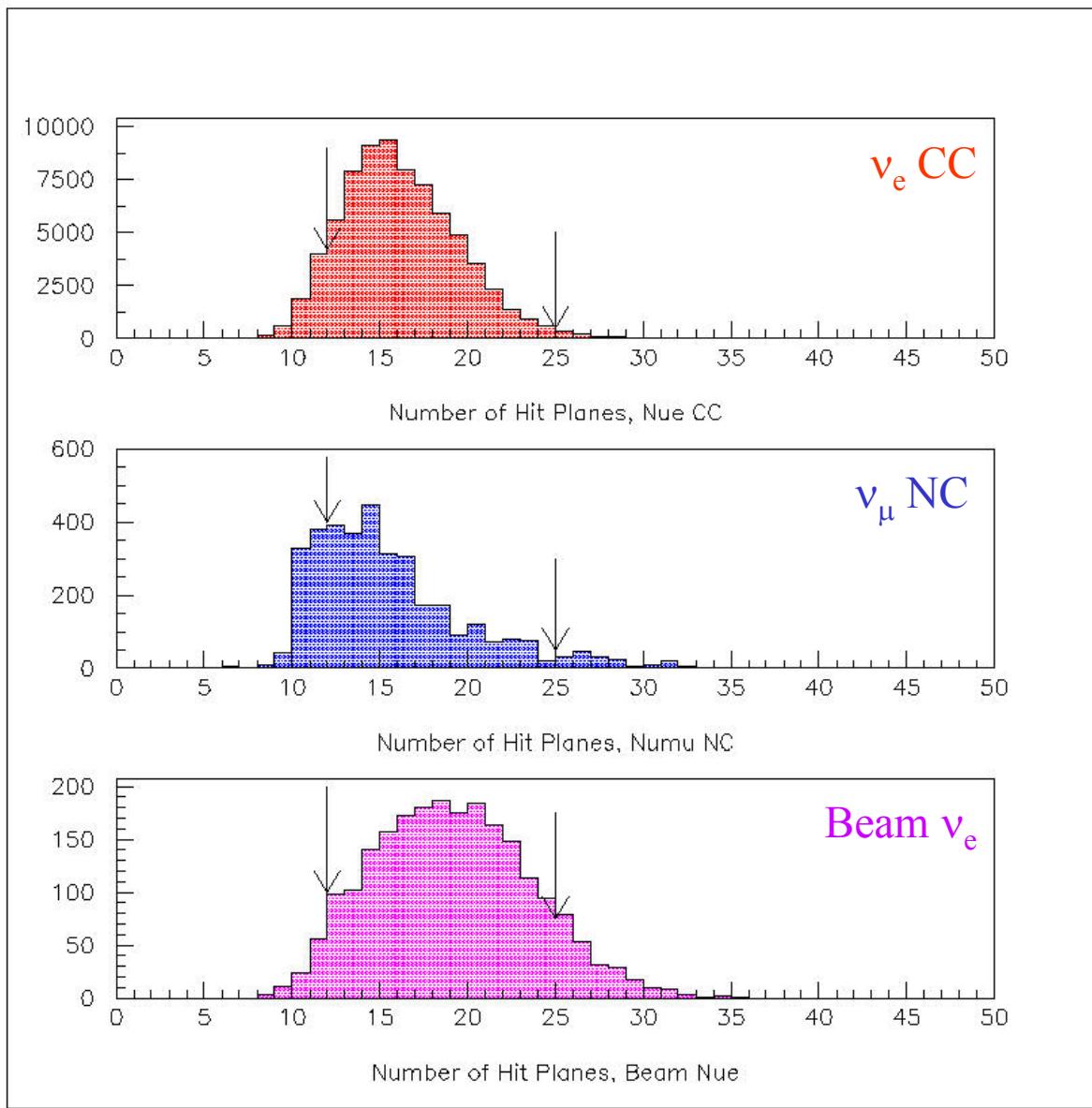
Cut distributions are weighted, successive



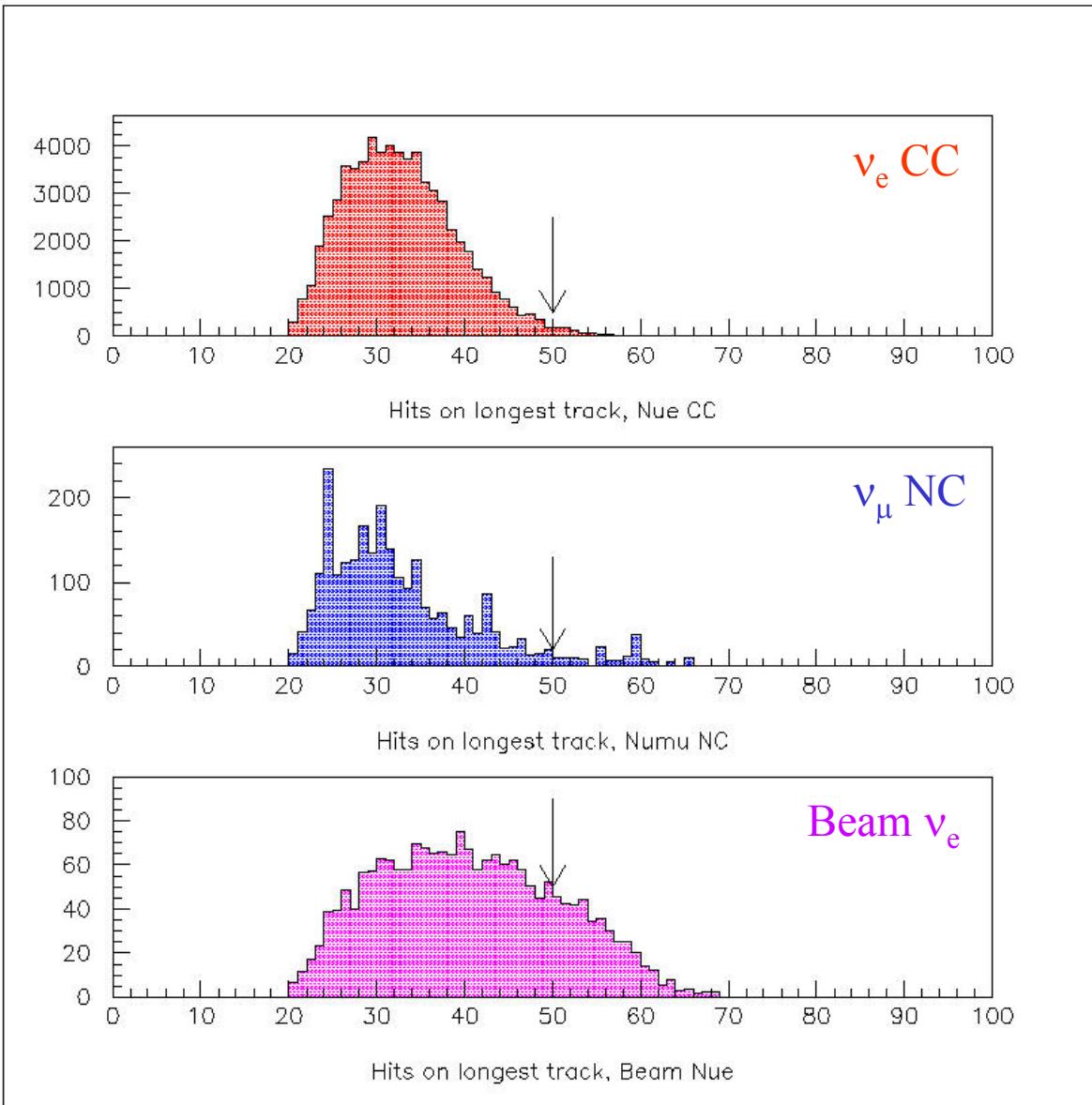
Cut distributions are weighted, successive



Cut distributions are weighted, successive

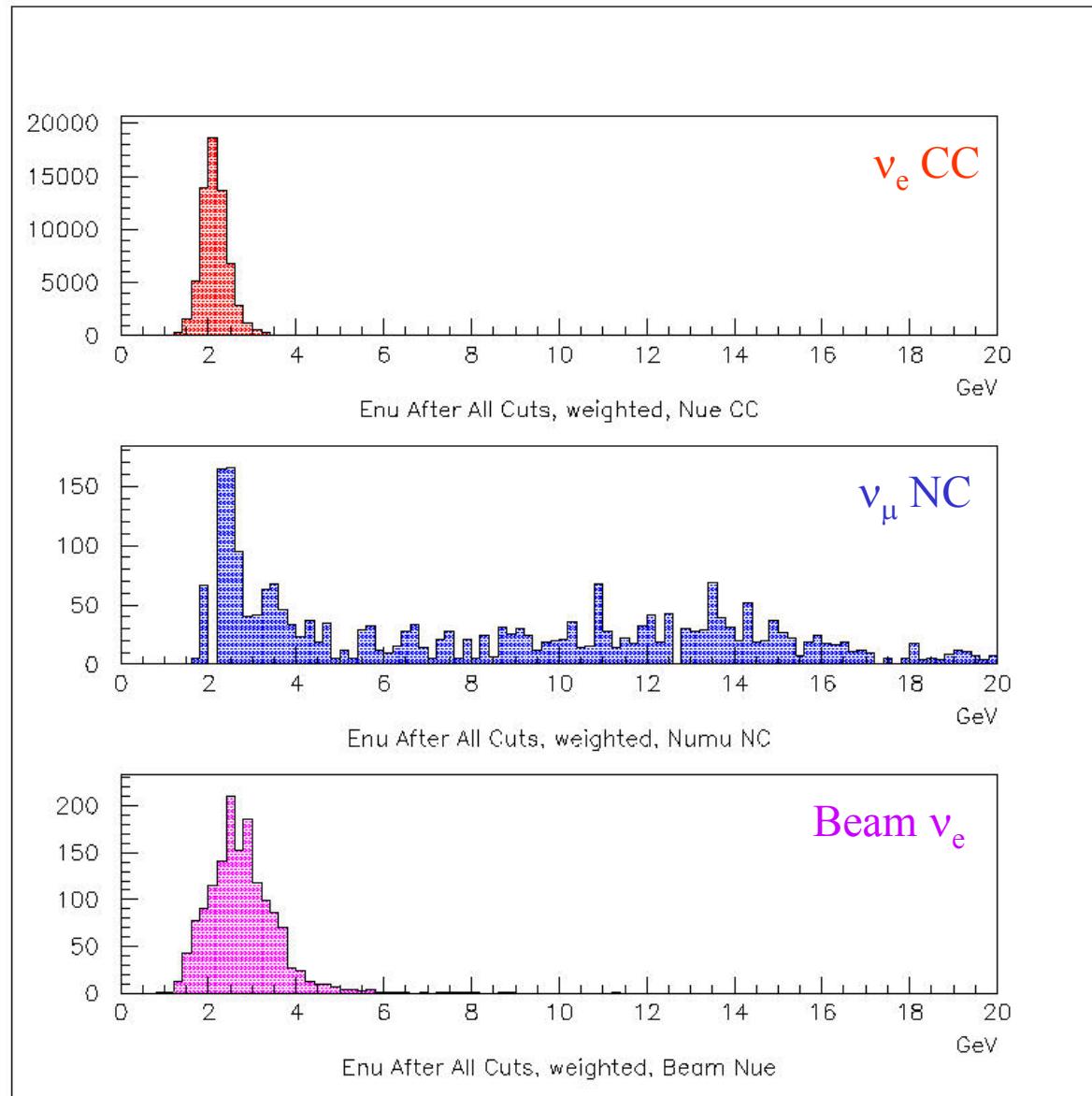


Cut distributions are weighted, successive

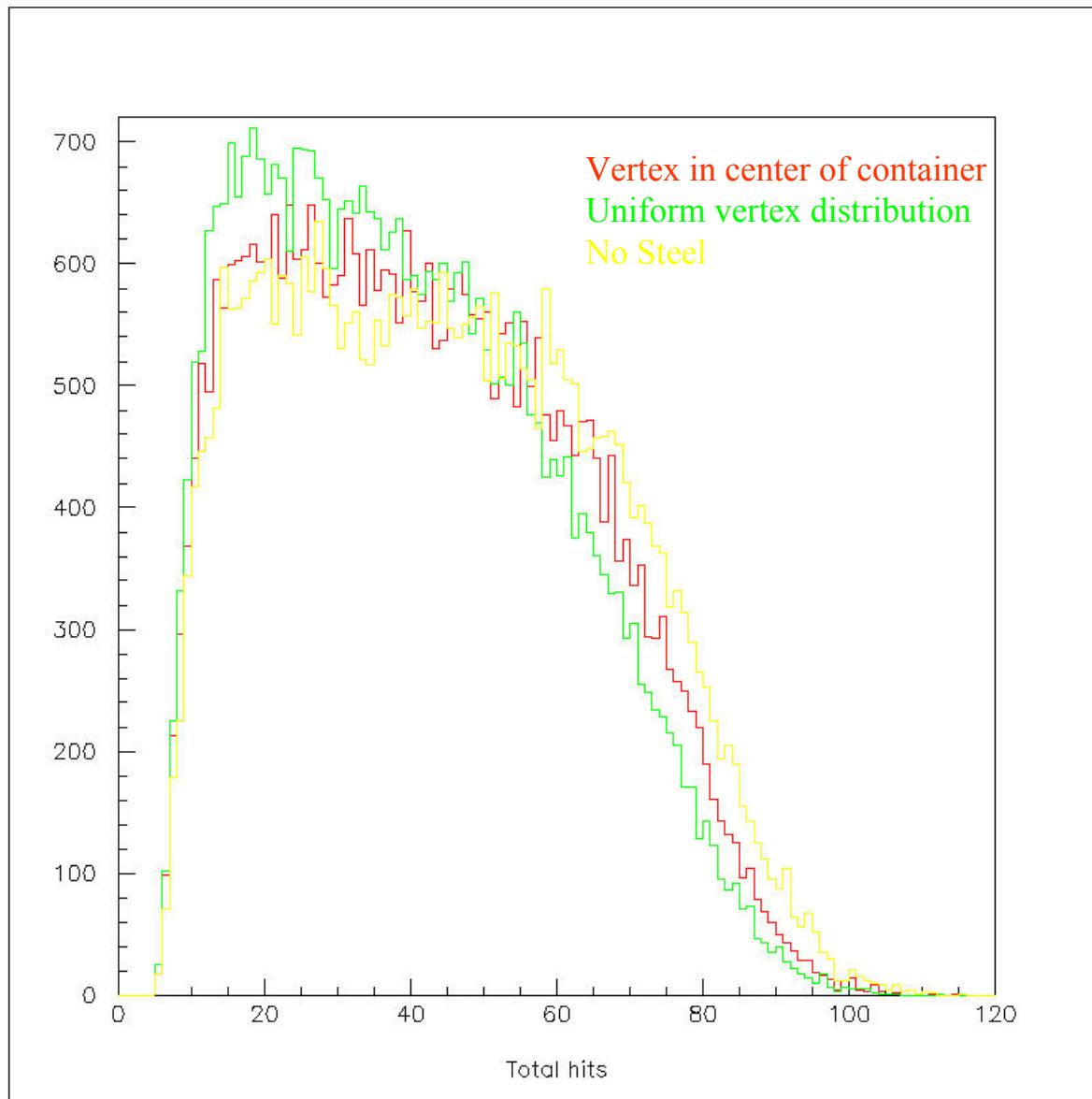


Cut distributions are weighted, successive

## Energy Distribution of Surviving Events



# Total Hit distribution for $\nu_e$ CC



Distributions normalized  
to total number of hits

Steel reduces number  
of hits

# Results

	v <sub>e</sub> CC Container Center	v <sub>μ</sub> NC Container Center	Beam v <sub>e</sub> Container Center	v <sub>e</sub> CC Uniform Vertex	v <sub>μ</sub> NC Uniform vertex	Beam v <sub>e</sub> Uniform Vertex
<b>Total Events (weighted)</b>	50,530	99,842	5,571	202,150	397,224	21,196
<b>Reconstruction Cuts</b>	40,971	28,463	1,817	160,440	110,648	7,238
<b>Total Hits between 30 - 100 (25 - 100)</b>	33,956	9,419	1,149	138,141	45,648	4,783
<b>Ave hits/plane ≥ 1.6 in each view</b>	28,900	5,598	1,057	110,588	23,738	4,225
<b>Track width &lt; 8.5 cm<sup>2</sup> in each view</b>	25,410	2,100	880	96,028	8,450	3,382
<b>Frac of hits on track &gt; 0.575 in each view</b>	21,002	1,052	621	78,957	4,476	2,321
<b>Number of hit planes bet 12 - 25 in each view</b>	19,006	782	545	66,660	2,628	1,972
<b>Hits on longest track bet 20 - 50 in each view</b>	18,648	724	413	65,606	2,465	1,529
<b>Efficiency</b>	<b>0.369</b>	<b>0.007</b>	<b>0.074</b>	<b>0.324</b>	<b>0.006</b>	<b>0.072</b>
<b>Number of Events (50 kt, 5 yr)</b>	<b>246.8</b>	<b>48.1</b>	<b>34.2</b>	<b>216.7</b>	<b>41.3</b>	<b>33.3</b>
<b>FOM</b>	<b>27.2</b>			<b>25.1</b>		

# Results

	$\nu_e$ CC Vertex in Absorber	$\nu_\mu$ NC Vertex in Absorber	Beam $\nu_e$ Vertex in Absorber	$\nu_e$ CC Uniform Vertex	$\nu_\mu$ NC Uniform vertex	Beam $\nu_e$ Uniform Vertex
<b>Total Events (weighted)</b>	18,153	349,557	18,652	202,150	397,224	21,196
<b>Reconstruction Cuts</b>	145,735	101,039	6,575	160,440	110,648	7,238
<b>Total Hits between 30 - 100 (25 - 100)</b>	126,235	41,917	4,333	138,141	45,648	4,783
<b>Ave hits/plane <math>\geq 1.6</math> in each view</b>	101,207	21,788	3,837	110,588	23,738	4,225
<b>Track width <math>&lt; 8.5 \text{ cm}^2</math> in each view</b>	88,021	7,824	3,093	96,028	8,450	3,382
<b>Frac of hits on track <math>&gt; 0.575</math> in each view</b>	72,404	4,165	2,126	78,957	4,476	2,321
<b>Number of hit planes bet 12 - 25 in each view</b>	61,410	2,437	1,809	66,660	2,628	1,972
<b>Hits on longest track bet 20 - 50 in each view</b>	60,444	2,279	1,402	65,606	2,465	1,529
<b>Efficiency</b>	<b>0.333</b>	<b>0.006</b>	<b>0.66</b>	<b>0.324</b>	<b>0.006</b>	<b>0.072</b>
<b>Number of Events (50 kt, 5 yr)</b>	<b>222.7</b>	<b>41.3</b>	<b>30.5</b>	<b>216.7</b>	<b>41.3</b>	<b>33.3</b>
<b>FOM</b>	<b>26.3</b>			<b>25.1</b>		

## Comparison with Previous Results

Last Time	$v_e$ CC Container Center	$v_\mu$ NC Container Center	Beam $v_e$ Container Center	$v_e$ CC Uniform Vertex	$v_\mu$ NC Uniform vertex	Beam $v_e$ Uniform Vertex
Efficiency	0.369	0.0009		0.326	0.002	
Number of Events (50 kt, 5 yr)	270.3	12.6	25	238.6	28.5	25
FOM		44.1			32.6	

This Time	$v_e$ CC Container Center	$v_\mu$ NC Container Center	Beam $v_e$ Container Center	$v_e$ CC Uniform Vertex	$v_\mu$ NC Uniform vertex	Beam $v_e$ Uniform Vertex
Efficiency	0.369	0.007	0.074	0.324	0.006	0.072
Number of Events (50 kt, 5 yr)	246.8	48.1	34.2	216.7	41.3	33.3
FOM		27.2			25.1	

- Signal efficiencies very similar
- Backgrounds larger
- FOM smaller
- Difference between center of container and Uniform vertex smaller

## Summary

- New more realistic simulation implemented with better container description.  
Inefficiency and cross-talk effects now included.
- Cross-talk likely smaller than currently implemented. Smaller gaps between containers possible (J. Cooper)
- $\nu_e$  efficiency similar to last time. Background larger.
- Electron efficiency and background rejection attainable with containerized detector appear reasonable, *but you do pay a price in electron efficiency.*

Still to do:

- Simulate  $\nu_\mu$  CC
- Add noise?
- Explicitly implement a monolithic detector in GEANT for comparison
- Categorize  $\nu_\mu$  NC events that pass cuts and  $\nu_e$  CC events that fail cuts.
- Get some other people to look at GEANT output (Leslie).